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Joint High Speed Sea Truck

By

Michael Brown

Robert Dvorak

Tom Lee

LTJG Joseph Marra

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This paper describes work performed at the Naval Surface Warfare Center Carderock Division in the Center for Innovation in Ship Design. The objective of the project was to expand on the design and analysis conducted by the "Seabase to Treeline Connector" Innovation Cell that completed work in August 2005.

The original project developed a new concept that addressed the task of moving military vehicles, troops and equipment from the Seabase to the treeline ashore. Several concepts were developed and decisions factors for the selection of the recommended solution were analyzed and described in the original report.

The objective of this project was to define in more detail the "Seabase to Treeline" Connector platform that could fulfill the original objectives plus several additional prioritized mission capabilities and assess the new design with respect to the required speed, range, roll period and operational Sea State.

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Abstract

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The team would like to thank their mentors for their invaluable assistance and support:

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Introduction

Background

The “Seabase to Treeline Connector’s Innovation Cell’s objective was to develop a new concept that addressed the problem of delivering troops, military vehicles and equipment from the Seabase to the treeline, shown in Figure 1, in less than 8 hours. The Innovation Cell determined that a combination of a “Seabase to Beach” connector and a “Beach to Treeline” connector was the optimum solution to this problem. An analysis of the options available to meet the requirements of this solution was conducted, and based on those results, platforms were chosen for the system:

- “Seabase to Beach” connector – Heavy Lift Trimaran (HLT)
- “Beach to Treeline” connector – Self Propelled Hover Barge (SPHB)

The HLT was renamed the Joint High Speed Sea Truck (JHSST.)

Project Objectives

The objective of this project was to refine the design of the JHSST to encompass defined and prioritized mission capabilities in addition to its function as the “Seabase to Beach” connector of the “Seabase to Treeline” system, and to detail the design of the JHSST to achieve specified performance characteristics desirable to the JHSST’s performance in its proposed mission areas.

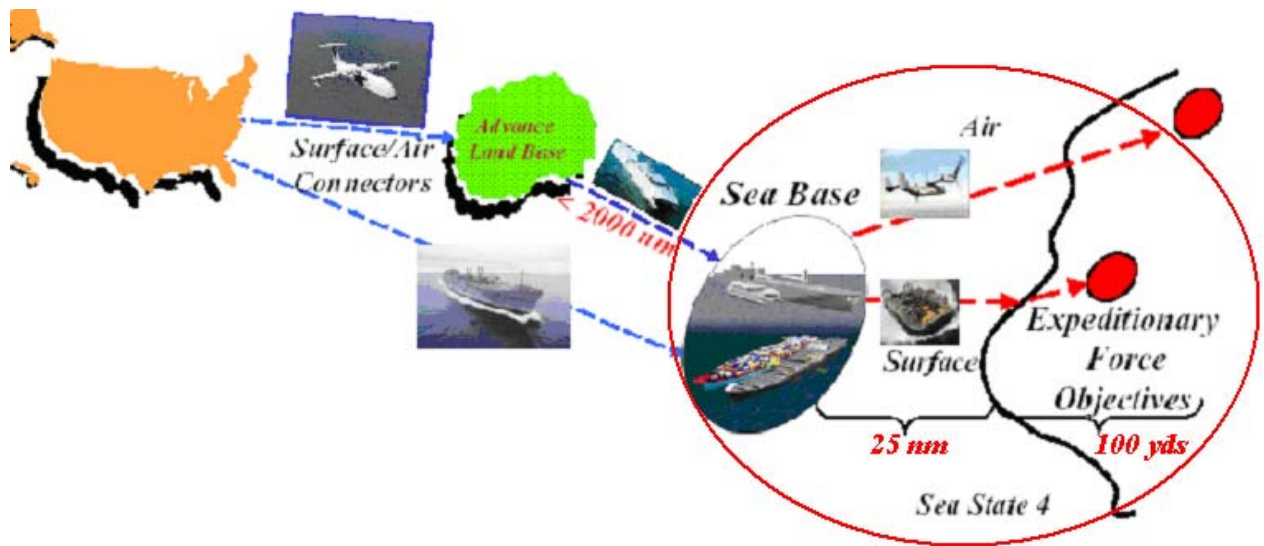


Figure 1 “Seabase to Treeline” Innovation Cell Focus

Mission Definition

The mission of the JHSST is to function as the “Seabase to Beach” connector as part of the “Seabase to Treeline” connector system as detailed in the Innovation Cell’s conclusions.

Additionally, the JHSST was to perform several secondary mission capabilities:

- Function as a support platform for Homeland Security related missions
- Be utilized in a short sea shipping system
- Maintain a capability to function as a commercial heavy lift ship
- Be capable of transporting damaged ships or large military cargo

Primary Mission

As previously stated, the primary mission of the JHSST is to function as the “Seabase to Beach” connector as part of the “Seabase to Treeline” connector system.

The Innovation Cell conducted an analysis of the mission requirements, payload and projected operating environment of the “Seabase to Treeline” connector system. Through an analysis of different components with which to comprise the “Seabase to Treeline” connector system, impacting factors on the selection of the platforms for these components, and a discussion of a number of possible solutions, the JHSST was chosen as the most viable solution.

The mission requirements, payload and projected operating environment were maintained as basic mission requirements and constantly considered during the design revision of the JHSST.

Payload

The assumed cargo is the surface element of a 2015 Marine Expeditionary Brigade (MEB) as projected by the United States Marine Corps (USMC) Combat Development Command¹. The cargo consists of personnel and a variety of wheeled and tracked vehicles, as described in Appendix A. The cargo totals approximately 5800 metric tons, occupying a footprint of 17000 square meters. All equipment is currently in the USMC inventory, with the exception of the Q46 Fire Finder Radar, whose size was estimated using similar radar.

Mission Requirements

The “Seabase to Treeline” connector system is required to deliver the payload from the seabase to the treeline in less than eight hours, so that an operation may take place under the cover of darkness.

Projected Operating Environment

This system is proposed to function in a seabase environment, defined as a collection of ships and other platforms offshore designed to sustain a force for an extended period of time in order to minimize the operational reliance on shore infrastructure.

The environment in which this system will operate is a sensitive littoral region. The maritime element of this region includes shoal water, varying currents produced by inland waters, and mine danger areas. The terrestrial environment is projected to be an unimproved beach, mud and swamp area, which contains 6.1 meter ditches, 1.5 meter vertical obstacles and ten degree gradients¹. Additionally, the terrestrial region is assumed to be secured, but located in a hostile area.

Other Requirements and Assumptions

Amplifying details and specifics characteristics were also defined for this design:

- The JHSST must be capable of achieving 24 knots. Additionally, the feasibility of the JHSST achieving 30 knots should be considered.
- The JHSST should include semi-submersible capabilities.
- The JHSST must have a range of 6000 nautical miles at 24 knots.
- The JHSST must achieve a roll period of approximately 15 seconds in an unballasted condition.
- The system must be able to operate in sea state 4. Additionally, the feasibility of the JHSST achieving operational capability in sea state 5 should be considered.
- The JHSST must contain a dynamic positioning system.
- The JHSST has no length, beam or draft restrictions; it must, however, be able to be constructed in a domestic shipyard.
- The JHSST must be capable of recovering, refueling and launching helicopters.
- The JHSST must be able to interface with other ships expected to comprise the sea base, such as the Mobile Landing Platform (MLP) and the Large Medium Speed Roll-on/Roll-off Ship (LMSR.)

The Innovation Cell defined the mission in detail with these assumptions, summarized in Figure 2:

- The seabase is located 25 nautical miles from the shoreline.
- The treeline is located approximately 91 meters from the shoreline.

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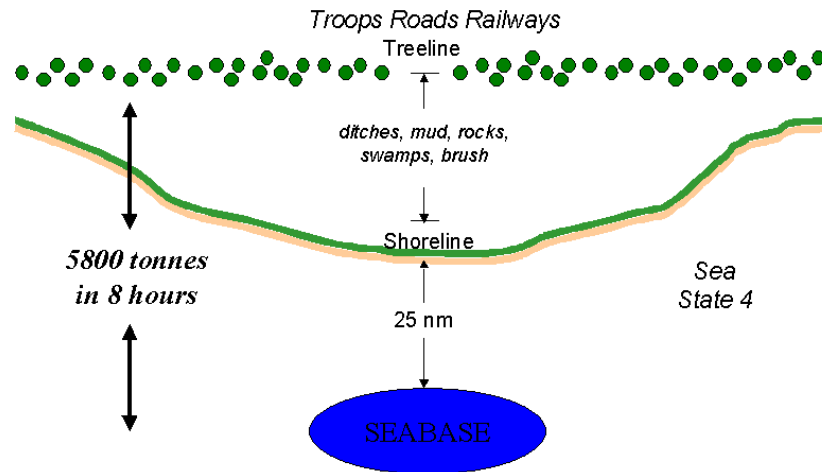


Figure 2 Innovation Cell Assumptions

Alternate Missions

Because of its innate capabilities, the JHSST has the potential to be used to perform a number of alternate missions. With forethought of their impact on the design of the JHSST and the payoff associated with the inclusion of these additional capabilities, the alternative mission capabilities were prioritized. An analysis of their inclusion into the design of the JHSST was conducted.

Homeland Security Logistics Support

Logistical support of Homeland Security missions was identified as the highest priority alternative mission for the JHSST. The mission capability calls for a vessel to be able to respond quickly, defined as approximately 3 days, in the wake of a terrorist attack or natural disaster, with a relevant mission package, capable of sustaining relief efforts for an extended period of time.

Major capabilities required of the JHSST to encompass this mission were identified:

- The JHSST must be able to achieve speeds that would ensure its response time would be approximately two to three days.
- The JHSST must have a draft shallow enough to access a significant amount of domestic coastline.
- The JHSST must be able to interface with other vessels and piers so that it may be easily loaded with equipment relative to its current mission.

Short Sea Shipping

The next highest priority alternate mission that was analyzed was use of the JHSST as an integral part of a short sea shipping system. The vessels involved in this mission would transport commercial trucks and their cargo between two ports along the same coastline efficiently, economically, and quickly in an effort to reduce congestion of terrestrial transportation infrastructure.

The JHSST would require certain capabilities to support this mission:

- The JHSST must have a draft shallow enough to access major domestic ports.
- The JHSST must be able to interface with piers easily and achieve a high throughput of commercial trucking to support the systems overall efficiency.
- The JHSST must be able to achieve high speeds to offer similar delivery times and thus become a viable option for the transportation of cargo.

Commercial Heavy Lift

Functionality as a commercial heavy lift ship was the next highest priority alternative mission identified for the JHSST.

For the JHSST to function as a commercial heavy lift ship, it must be able to submerge and secure a vessel to its topside deck area for transportation.

Transportation of Large Military Cargo and Damaged Ships

The transportation of large military cargo and damaged ships was the lowest priority mission capability analyzed. A vessel capable of transporting large military cargo and damaged vessels would use its capacity for carrying cargo, topside deck area, and heavy lift capability to transport aircraft, ships or irregularly shaped cargo.

The analysis was conducted using the assumption that the largest and heaviest cargo would be a damaged Flight IIA Arleigh Burke Class destroyer.

Project Team

This project team was formed by the Center for Innovation in Ship Design at the Naval Surface Warfare Center, Carderock Division. It contained four members, and was supported through constant interaction with four mentors.

Team Members	Field/Affiliation	School
Michael Brown	Marine Engineering/UK MOD DESG	Plymouth University
Robert Dvorak	Naval Architecture	Webb Institute
Tom Lee	Architecture	University of Minnesota
LTJG Joseph Marra	Electrical Engineering/ US Navy (NSWCCD)	Rensselaer Polytechnic Institute
Mentors	Company	Code
Jeffrey Hough	NSWCCD	20
Dr. Colen Kennell	NSWCCD	242
LCDR Russell Peters	NSWCCD	20
Mark Selfridge	NSWCCD	24

Table 1 Project Team

Analysis Tools

Computational and modeling tools used in this project are shown in Table 2.

Analysis	Tool
Arrangements	AutoCAD, Rhino3D, PhotoShop, Illustrator
Concept Animation	Bryce 5, Studio 7
Hullform Development	Rhino 3D
Hydrostatics	Rhino3D Marine
Programming	Microsoft Excel
Resistance/Power	“Effective Horsepower and Seakeeping Tests on a Trimaran Model ² .”

Table 2 Analysis Tools

Approach

The design of the JHSST commenced by analyzing the requirements of the vessels mission as the “Seabase to Beach” connector in the “Seabase to Treeline” connector system. With the requirements of the primary mission met, the project team engaged a process of collaborative brainstorming to identify design configurations to encompass the mission requirements of as many, and possibly all, of the prioritized alternative missions.

Design Options

Through collaboration with the groups mentors, several commonly adhered to design principles were identified. The project team focused on adopting these constraints in the design, but was not rigidly constrained by them:

- The vessel should have a length to depth ratio of 15 or less.
- The vessel should have a relative shallow draft (approximately 6-8 meters.)
- To minimize overall cost, the project team should focus on developing the smallest vessel to meet the requirements of the design.

Using the initial requirements, and while keeping these additional constraints in mind, four decision factors were decided upon to have impact on the primary mission and the inclusion of each alternative mission in the eventual design of the JHSST:

- Length
- Beam
- Topside Deck Area (surface area of stowage space topside)
- Cargo Deck Area (surface area of interior stowage spaces)
- SPHB Capacity (number of SPHB’s that can be carried onboard)

The manipulation of these factors, while maintaining effect on the overall design of the JHSST, can encompass each alternative mission area.

Design Option 1

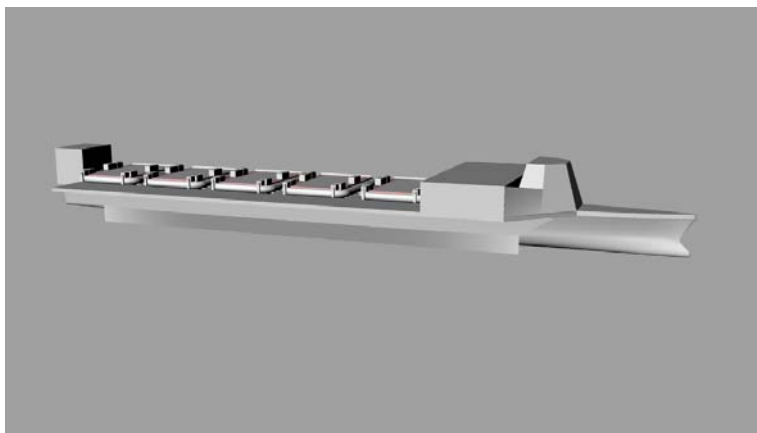


Figure 3 Design Option 1

Length	Beam	Topside Deck Area	Cargo Area	SPHB Capacity
245 m	53 m	8268 m ²	0 m ²	5

Table 3 Design Option 1

This option was developed in order to accommodate the size of a Flight IIA Arleigh Burke class destroyer. As shown in Figure 4, the hypotenuse of the rectangular topside deck area provides 165 meters to transport this vessel. Additionally, the increased length allowed space for the stowage of the entire payload topside, as well as an additional SPHB.



Figure 4 M/V Blue Marlin carrying USS Cole in 2000

Design Option 2

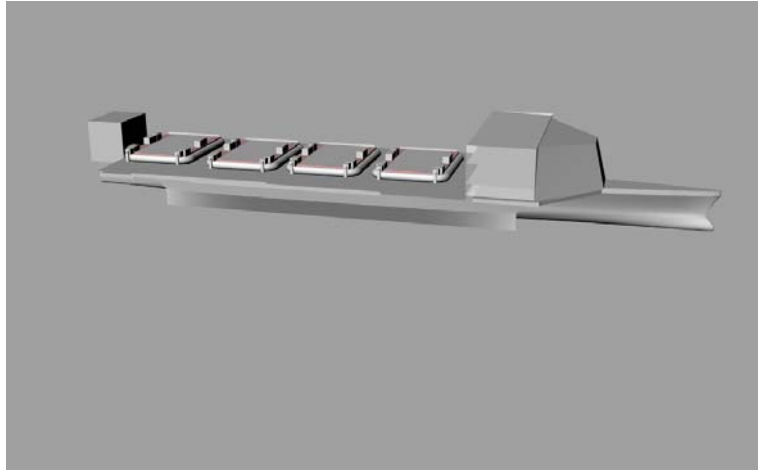


Figure 5 Design Option 2

Length	Beam	Topside Deck Area	Cargo Area	SPHB Capacity
227 m	53 m	6678 m ²	2544 m ²	4

Table 4 Design Option 2

As shown in Figure 5, this option provides capacity for four SPHB's on the topside deck area, as well 2544 m² of area for addition cargo housed in a three level superstructure.

Design Option 3

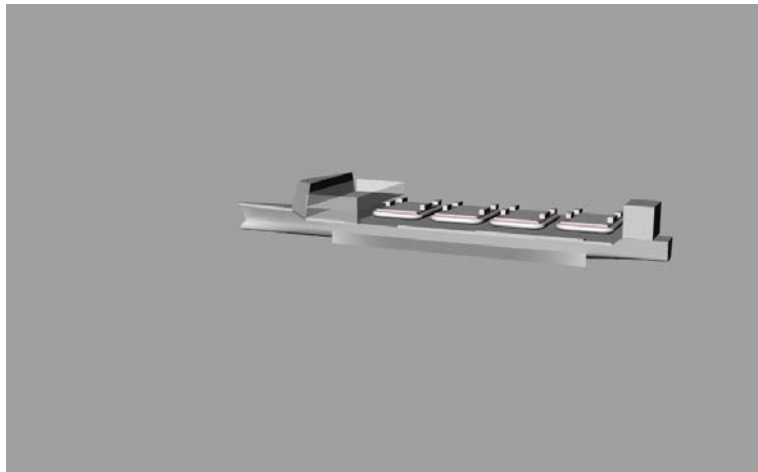


Figure 6 Design Option 3

Length	Beam	Topside Deck Area	Cargo Area	SPHB Capacity
239 m	53 m	6678 m ²	2544 m ²	4

Table 5 Design Option 3

Similar to Option 2, this option provides capacity for four SPHB's and 2544 square meters of area for cargo. Because it is now housed in a two level cargo superstructure, the cargo area requirement results in an increased length.

Design Option 4

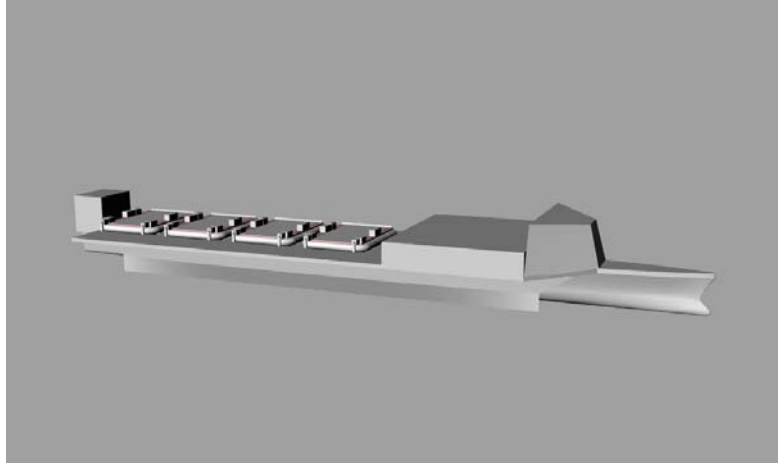


Figure 7 Design Option 4

Length	Beam	Topside Deck Area	Cargo Area	SPHB Capacity
263 m	53 m	6678 m ²	2544 m ²	4

Table 6 Design Option 4

As with Options 2 and 3, this option provides capacity for four SPHB's and 2544 square meters of cargo area. With the cargo area housed in a one level superstructure, the ship length increases over the previous two options.

Design Option 5

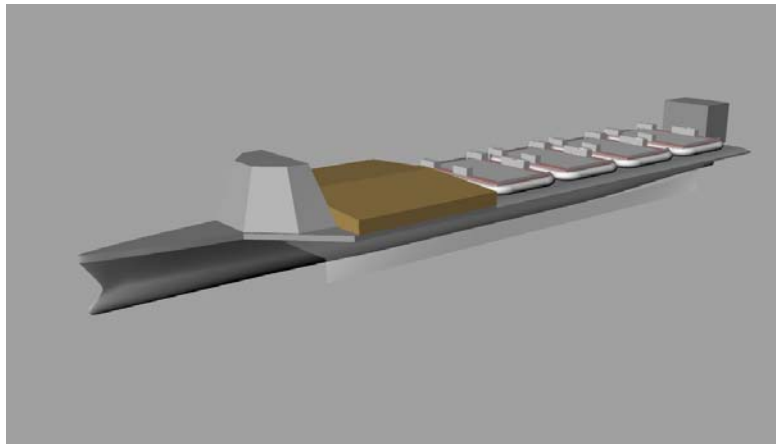


Figure 8 Design Option 5

Length	Beam	Topside Deck Area	Cargo Area	SPHB Capacity
263 m	53 m	6678 m ² / 8268 m ²	2544 m ² / 0 m ²	4 or 5

Table 7 Design Option 5

As shown in Figure 8, this option includes a retractable superstructure, and thus its capacity varies depending on its configuration. With an expanded superstructure, this option provides space for four SPHB's and 2544 square meters of cargo area. When the superstructure is retracted, the vessel provides a topside deck area capacity large enough to transport a Flight IIA Arleigh Burke class destroyer.

Design Option 6

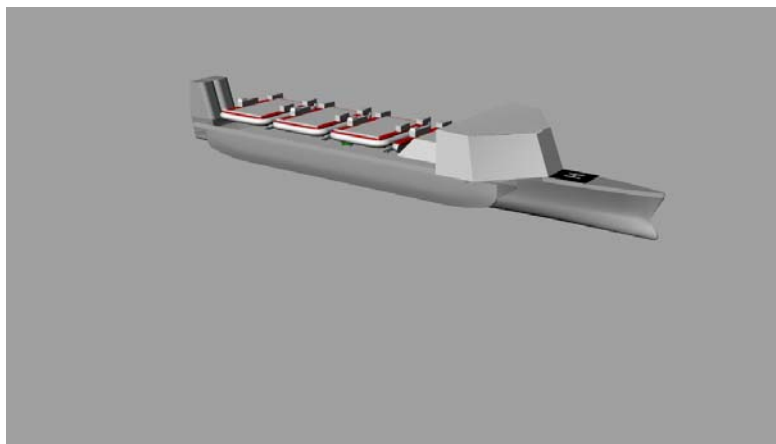


Figure 9 Design Option 5

Length	Beam	Topside Deck Area	Cargo Area	SPHB Capacity
215 m	53 m	6678 m ²	6678 m ²	4

Table 8 Design Option 6

This option involves a drastically different approach to the previous options, as the 6678 square meters of cargo capacity is housed on the first deck below the topside deck area. Capacity for four SPHB's is maintained, but as a result of this configuration, the ship length is significantly reduced.

Trade-Off Study

An analysis was conducted of the specific characteristics of each proposed design option and their relationship to the primary and alternate mission capabilities. The objective of this analysis was to conclude what impact each alternate mission capability had on the design.

The matrix shown in Table 9 was constructed using the following criteria:

- 0 – The design option does not meet the mission requirements.
- 1 – The design option meets some of the mission requirements, or partially meets the mission requirements.
- 2 – The design option fully meets the mission requirements.
- 3 – The design option fully is over-engineered and goes beyond meeting the mission requirements.

	“Seabase to Beach” Connector	Homeland Security Support	Short Sea Shipping	Commercial Heavy Lift	Large Military Cargo / Damaged Ships
<i>Option 1</i>	3	1	1	1	1
<i>Option 2</i>	2	2	2	2	0
<i>Option 3</i>	2	2	2	2	0
<i>Option 4</i>	2	2	2	2	0
<i>Option 5</i>	3	2	2	2	1
<i>Option 6</i>	2	2	2	2	0

Table 9 Design Option Analysis

	Length to Depth Ratio
<i>Option 1</i>	14.4
<i>Option 2</i>	13.3
<i>Option 3</i>	14.1
<i>Option 4</i>	15.4
<i>Option 5</i>	15.4
<i>Option 6</i>	12.6

Table 10 Design Option Length to Depth Ratio

Conclusion

Based on the analysis of the specifics each of proposed design option and their relationship to the primary and alternate priorities missions, two conclusions were reached:

- Designing the JHSST to transport large military cargo and damaged ships, using the assumption that such a vessel should possess the capability to transport a Flight IIA Arleigh Burke Class destroyer, yields the greatest impact on the result. Assuming a Flight IIA Arleigh Burke Class destroyer, at a length of 155.29 meters, requires 165 meters of uninterrupted point-to-point topside space. Using a beam of 53 meters, consistent with each other proposed design option, the 165 meter requirements translates into a cargo deck section longitudinal length of approximately 156 meters, which is 30 meters longer than the 126 meters required to situate four SPHB's adjacent to each other longitudinally.

Because of this impact and combined with this missions low priority, the project team concluded that the design should not include the requirements of transportation of large military cargo and damaged ships. It should be noted however, that this conclusion is largely based on the assumption that the cargo requirement is a Flight IIA Arleigh Burke class destroyer. The JHSST does not possess the capability of transporting a ship this size, but is able to transport smaller ships, as well as cargo and aircraft.

- As shown in Table 9 and based on the aforementioned conclusions, Options 2, 3, 4 and 6 all proved to be desirable configurations for the design of the JHSST. Using the rationale previously mentioned, distinction between these options was made through comparison of each options length to depth ratio, their potential for high speeds based on their overall size, and their projected relative costs. Option 6 was therefore chosen to be the most effective design solution.
- After concluding that the best design was Option 6, the project team identified certain advantages of aft superstructure over a forward superstructure. Exploring this option led the team to determine that each design option's variables were identical if the option had been developed with an aft superstructure, and thus the findings of the analysis were still applicable. The team did note the effect of an aft superstructure on the ships longitudinal center of gravity, and conducted an analysis of this discussed in a later section.

Joint High Speed Sea Truck Design

Concept of Operations (CONOPS)

The concept of operations (CONOPS) for the Joint High Speed Sea Truck as originally identified by the Innovation Cell was adhered to and further described during the development of the JHSST design. The CONOPS is categorized into five phases:

- Phase I – The JHSST/SPHB system transits from the seabase to the standoff distance
- Phase II – The JHSST ballasts and heels to deploy the loaded SPHB's from the cargo deck of the JHSST.
- Phase III – The SPHB's transit to the beach, disembark their cargo, and complete 1 round trip by returning to the JHSST. The SPHB's continue to complete round trips until all cargo is delivered to the beach.
- Phase IV – The SPHB's are recovered by the JHSST after completing their final round trip.
- Phase V – JHSST deballasts and returns from the standoff distance to the seabase.

Figure 10 shows AMERICAN CORMORANT conducting operations similar to the CONOPS identified.



Figure 10 AMERICAN CORMORANT during cargo offload

Event Model

The “Seabase to Treeline” Connector Innovation Cell determined the principal characteristics of the JHSST/SPHB system by constructing an event model using the following independent and dependent variables:

- Independent Variables:
 - Standoff Distance
 - Number of JHSST’s
 - Number of SPHB’s per JHSST
 - JHSST Velocity
 - SPHB Velocity
- Dependent Variables:
 - SPHB Cargo Deck Area
 - JHSST Cargo Deck Area
 - Mission Time

The innovation cell conducted an analysis of these variables and the following results were determined to maximize effectiveness and redundancy and minimize cost and risk:

- 4 nautical mile standoff distance
- 4 JHSST’s
- 4 SPHB’s per JHSST
- JHSST Velocity = 24 knots
- SPHB Velocity = 8 knots
- 550 square meters SPHB cargo deck area
- 6,000 square meter JHSST cargo deck area
- 6.5 hour total mission time
 - 2 trips per SPHB (32 total trips)
 - 2.6 hour round trips

Hullform

The implementation of a trimaran hullform with heavy lift technology was seen as the most viable solution to the meet the mission requirements. The proposed hullform includes a center hull capable of containing a fuel system for increased range and side hulls instrumental in a ballast system capable of achieving semi-submersion and trimming. It also offers increased stability, lower resistance, better seakeeping properties, and a more cargo deck area than a monohull of comparable size.

The original innovation cell used a modified Rapid Strategic Lift Ship (RSLS) center hull and basic side hulls. Though the lengths were extended to meet the requirements of the design, the center and side hullforms were essentially maintained.

Parameter	Value
Length (Center Hull)	215 m
Length (Side Hulls)	141 m
Length (Open Deck)	126 m
Beam (Center Hull)	22 m
Beam (Side Hull to Side Hull)	42 m
Max Beam (Deck Edge to Deck Edge)	53 m
Depth (Overall)	37 m
Depth (Center Hull)	17 m
Depth (Side Hulls)	12 m
Design Draft	8.3 m
Deck Area	6678 m ²

Table 11 JHSST Hullform Characteristics

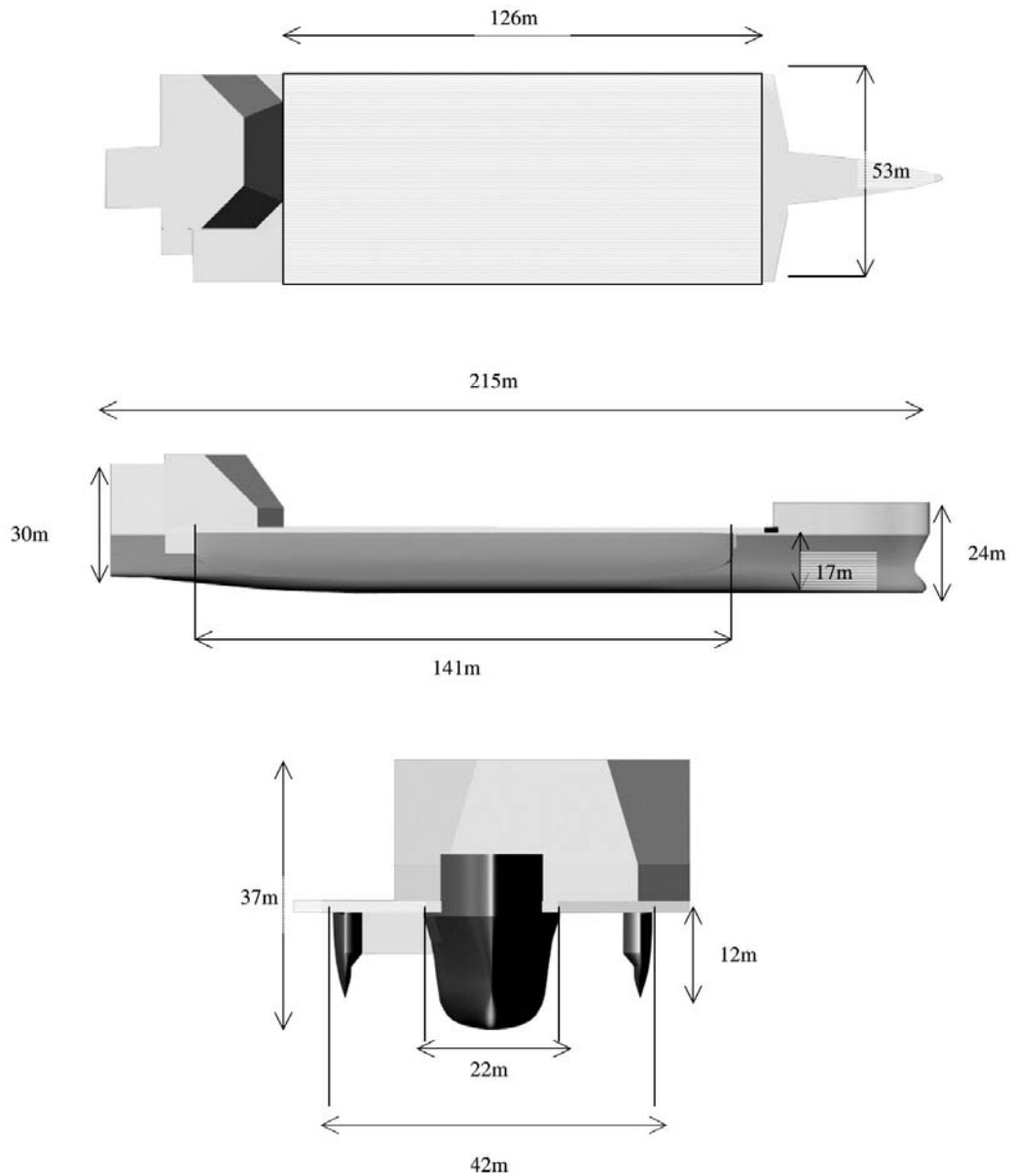


Figure 11 JHSST Hullform

Sea State

The JHSST is capable of sustained operation in sea state 5, defined as a sea state with wave height ranging from 2.4 meters to 3.66 meters and wave periods ranging from 2.5 to 12 seconds. With a freeboard of 11.7 meters, shown in Figure 11, the JHSST is minimally affected in sea state 5.

Deck Arrangements

The deck arrangement was chosen to maximize efficiency of loading and unloading operations and practicality for ship's company.

Machinery Spaces

The second deck is occupied by machinery spaces. The specifics of the propulsion plant are discussed in a later section.

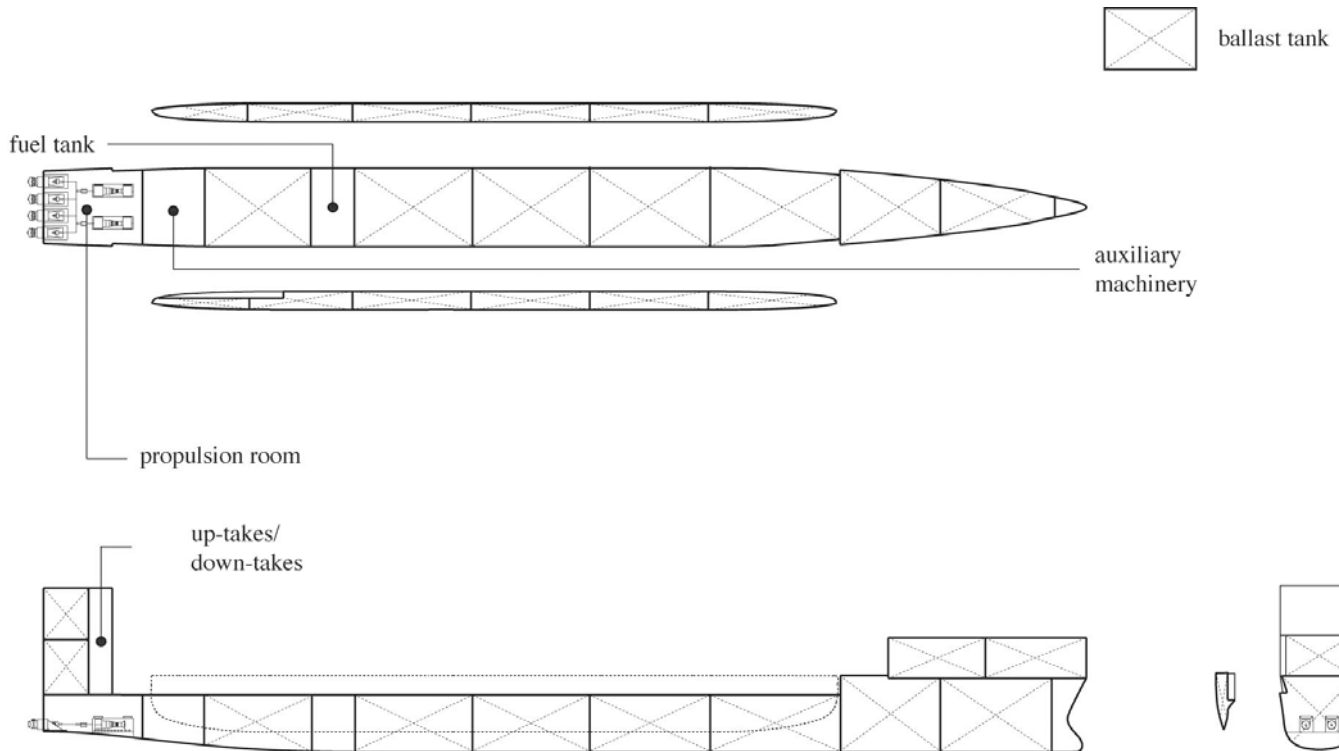


Figure 12 Machinery Spaces (Second Deck)

Cargo Deck Area

The cargo deck area, shown in Figure 13, is accessed via the main deck ramp or the stern ramp, and has capacity for 2893 square meters. A galley, conference room, two mess rooms, and two heads are housed within the cargo deck for transient personnel, shown in Figure 14.

Naval Surface Warfare Center Carderock Division
Joint High-Speed Sea Truck

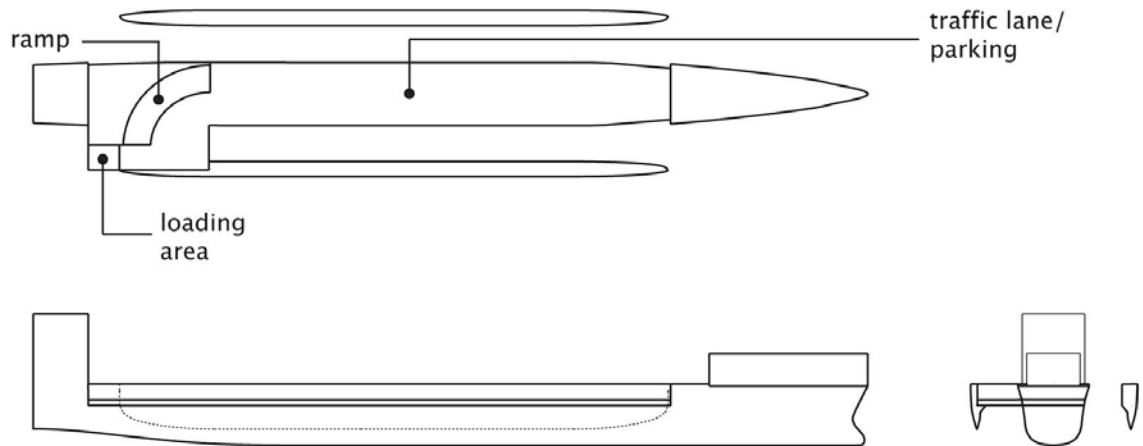


Figure 13 Cargo Deck (First Deck)

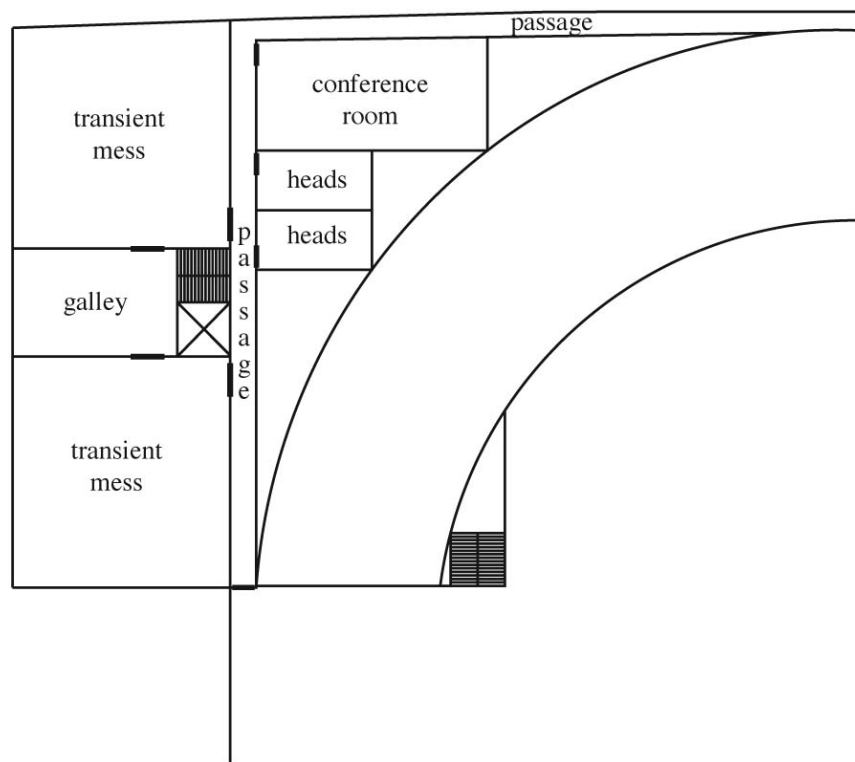


Figure 14 Cargo Deck Accommodations

Topside Deck Area (Main Deck)

The topside deck area was developed to maximize the efficiency and simplicity of unloading and loading operations, while minimally affecting the beam and length of the JHSST. The topside deck area contains space for four SPHB's, situated adjacent to each other with their stern towards the port side of the JHSST, as shown in Figure 13. The port side of the topside deck is curved, to facilitate the launch and recovery of the SPHB's. The topside deck area also contains space for two lanes of wheeled and tracked vehicle traffic, to be used during loading and unloading operations. As shown in Figure 12 and Table 11, the 10 meter wide traffic lanes provide enough space to accommodate the turning radius of any vehicle in the payload. The main deck also contains berthing, heads, showers, general workshops, stores and offices for transient personnel, as shown in Figure 17.

Vehicle	Turning Radius
M1A1	6.5 m
AAAV	10.1 m
M88A1	9.21 m
M1097	7.62 m
M198	7.77 m
LVS Mk 48	11.73 m
M101A2	12.19 m
M390	12.19 m
LAV	7.77 m
AVLB	9.44 m
MEWSS	7.77 m
MTVR	13.11 m
M9293/Q46	11.99 m
ABV	7.48 m

Table 12 MEB Turning Radius Data³

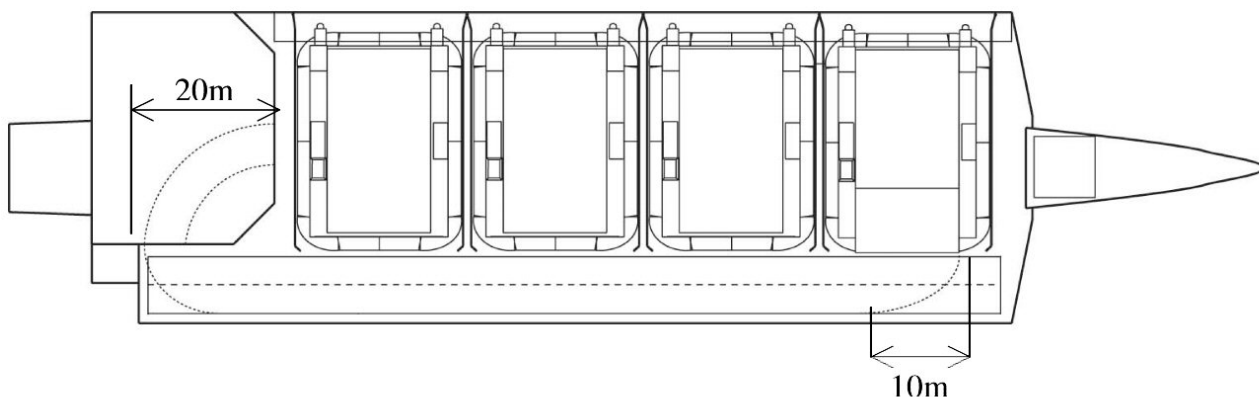


Figure 15 Topside Deck to Cargo Deck Ramp

Naval Surface Warfare Center Carderock Division
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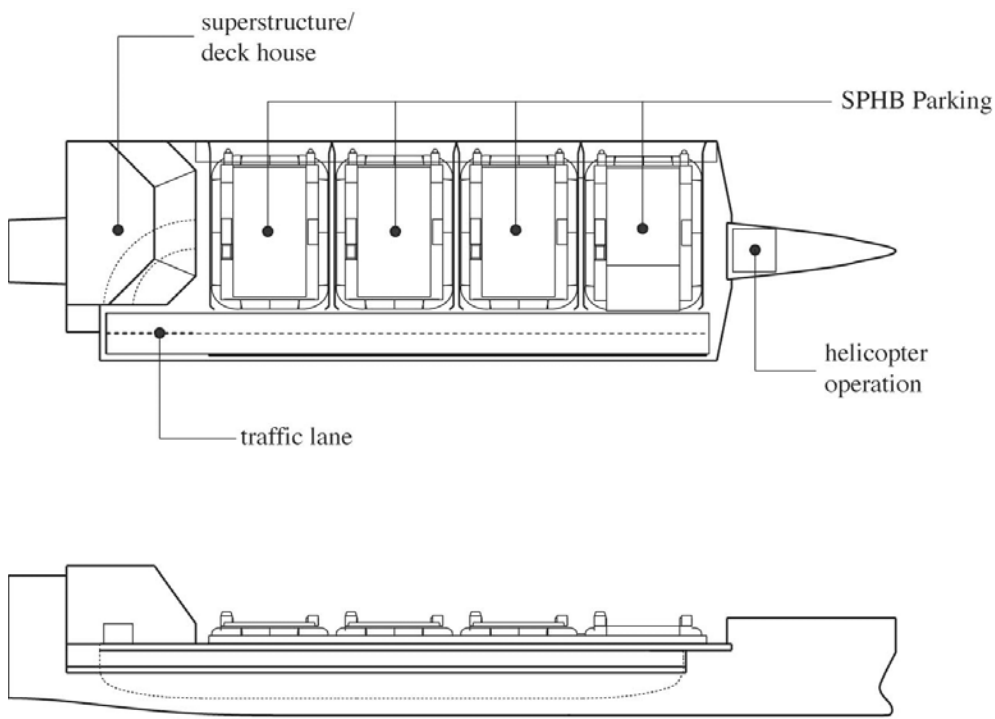


Figure 16 Topside Deck Area (Main Deck)

**Naval Surface Warfare Center Carderock Division
Joint High-Speed Sea Truck**

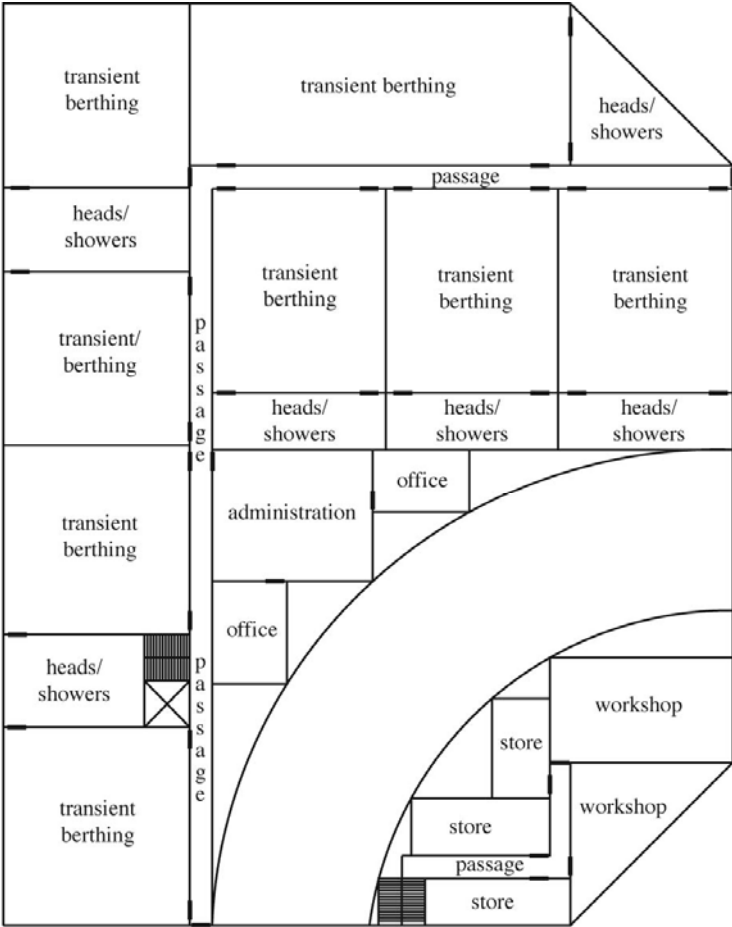


Figure 17 Main Deck Accommodations

Superstructure

The bridge, communications suite, officer staterooms, crew berthing spaces, and transient berthing spaces are housed in the superstructure.

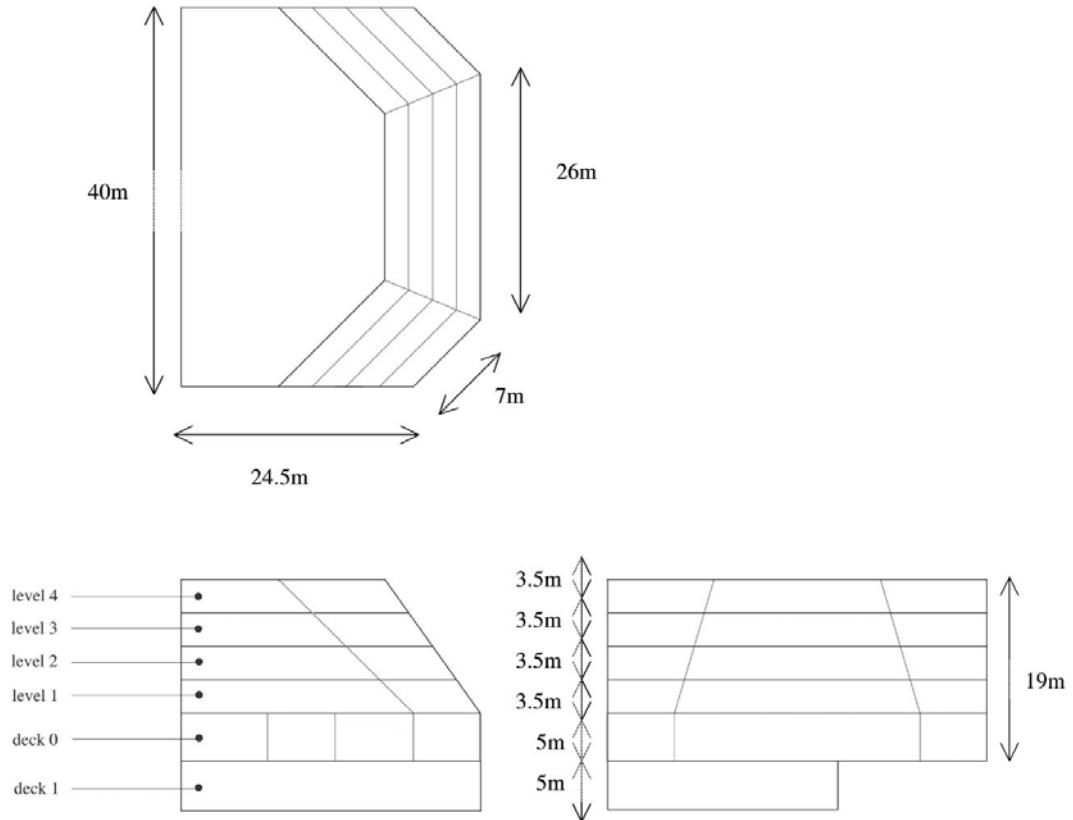


Figure 18 Levels and Dimensions of Superstructure

**Naval Surface Warfare Center Carderock Division
Joint High-Speed Sea Truck**

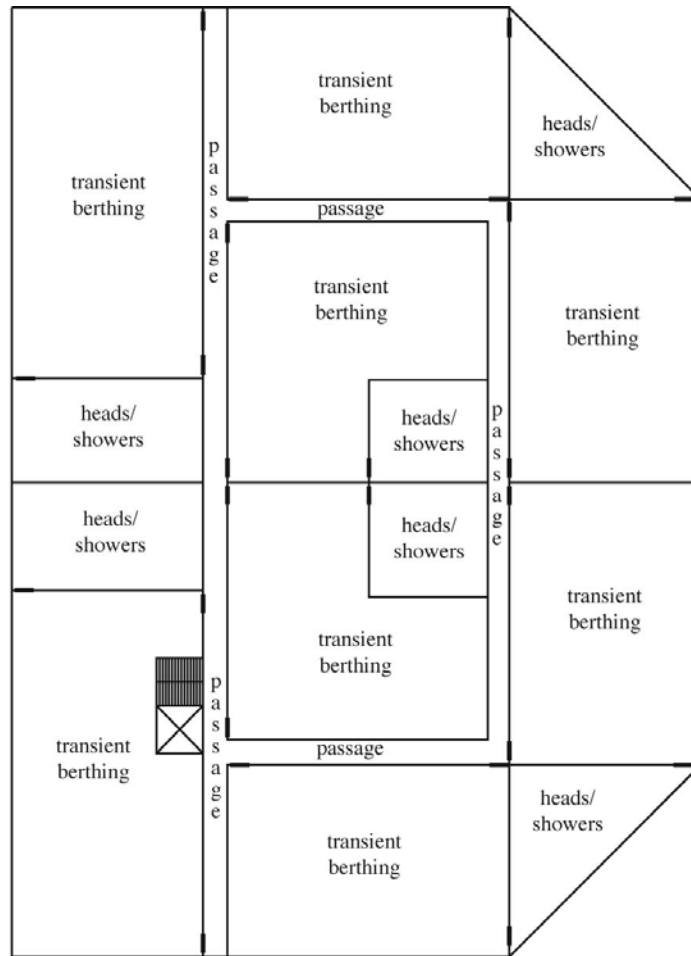


Figure 19 Superstructure (Level 1)

Naval Surface Warfare Center Carderock Division
Joint High-Speed Sea Truck

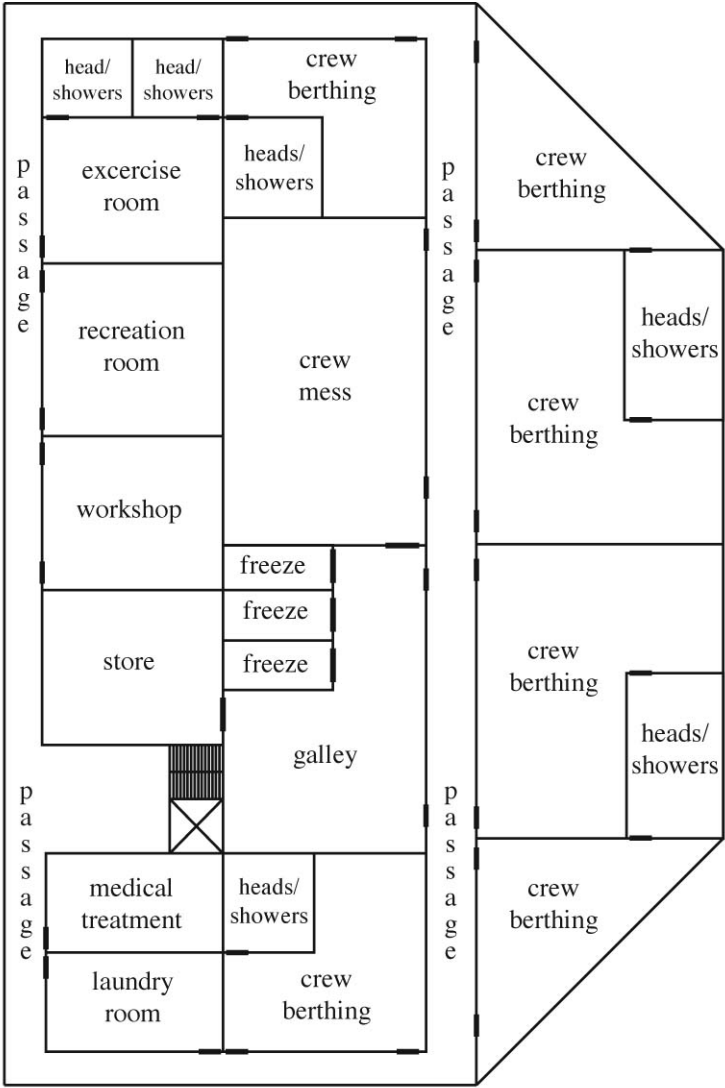


Figure 20 Superstructure (Level 2)

**Naval Surface Warfare Center Carderock Division
Joint High-Speed Sea Truck**

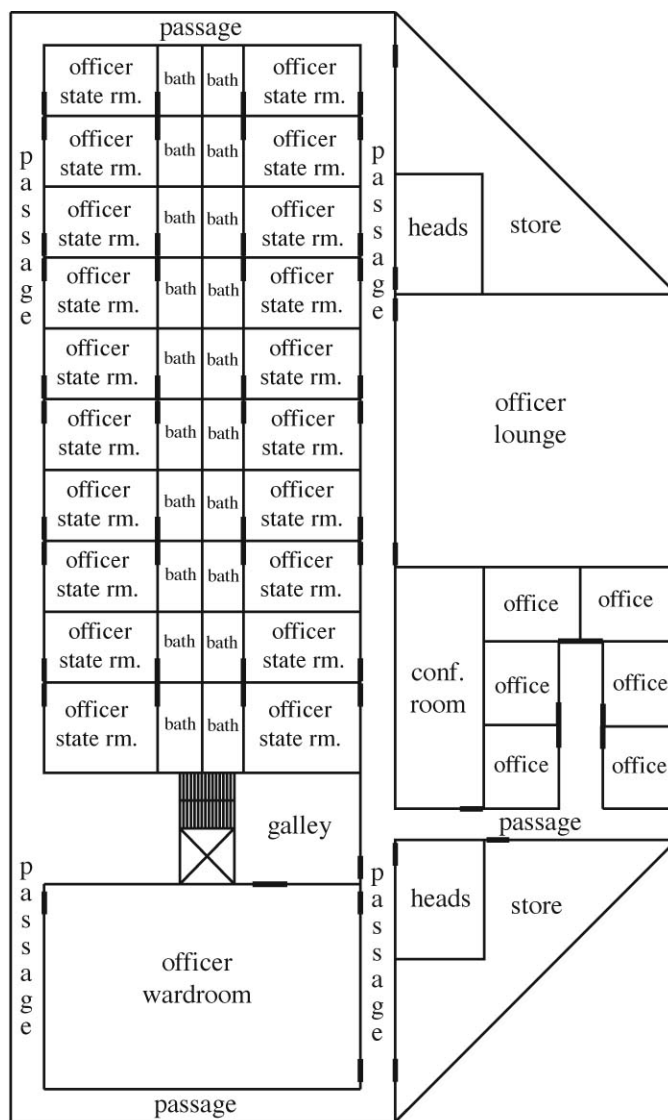


Figure 21 Superstructure (Level 3)

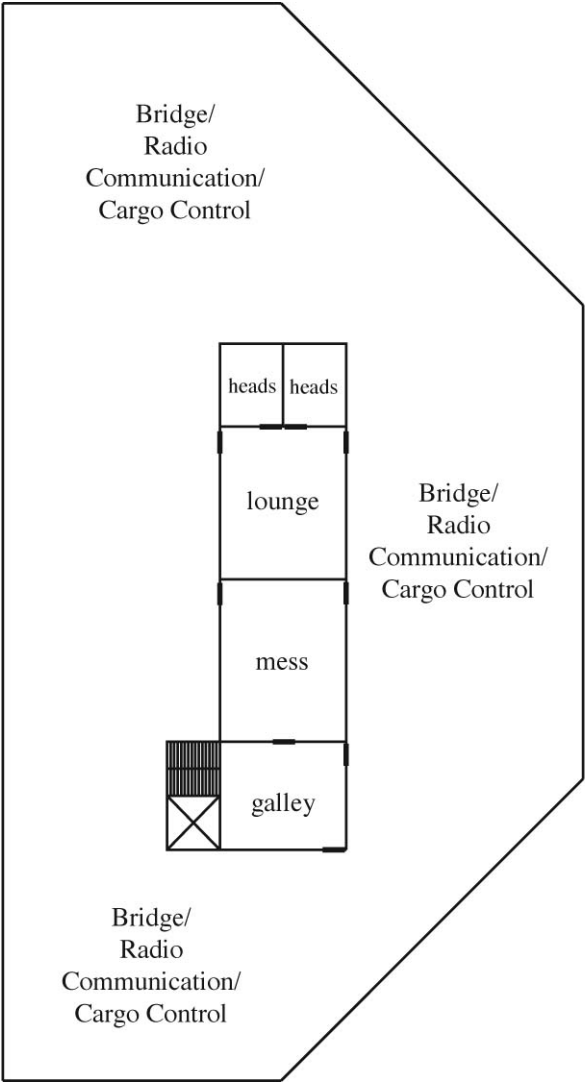


Figure 22 Superstructure (Level 4)

Habitability

Officer and crew accommodations are located on the second and third levels. The size of these accommodations was based on manning assumptions that were made on vessels of comparable size and current operations of similar throughput and capacity:

Category	Number of Personnel
Ship's Wardroom	15
Ship's Crew	50
(4) SPHB Officers	4
(4) SPHB Crew	48
Total	116

Table 13 Accommodations

Habitability spaces include the following:

- Single Staterooms for officers
- Group Berthing for crewmembers
- Private Head/Shower for officers
- Group Head/Shower for crewmembers
- Officer Wardroom and Lounge
- Crew Mess Room and Lounge
- Galley
- Freeze Room
- Exercise Room
- Recreation Room
- Administration Offices
- Ship Store
- Laundry
- Medical Treatment

These accommodations are housed in the spaces of the following area, consistent with commercial standards:

Category	Area (m ²)
Crew Berthing	315
Area per crewmember	3.21
Officer Berthing	216
Area per officer	11

Table 14 Accommodation Sizes

Transient accommodations are located in the first deck, main deck, and first level.

Transient habitability spaces include the following:

- Berthing (1,442 m² or 2.5 m² per transient individual)
- Heads/Showers
- Galley
- Mess Area/Lounge
- Administration Offices
- Ship's Store

Interface with other vessels

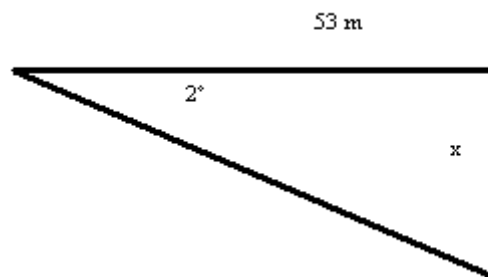
The JHSST will be an integral part of operations in the sea base, and thus is equipped with several interface options to support loading and loading:

- The JHSST has a freeboard height less than 11 meters. Combined with its ballasting capability, it can accommodate a med-moor or skin to skin cargo transfer on its topside deck area.
- The JHSST can be equipped with a stern ramp, granting immediate access to the cargo deck areas. Although not developed, the stern ramp should be capable of receiving cargo from a pier or other vessel both abreast and astern of the JHSST.
- The superstructure of the JHSST, situated aft of the topside deck area, provides commanders with a full field of vision of cargo loading operations.
- The superstructure of the JHSST does not extend to the entire beam of the topside deck area. This arrangements allows existing Roll-On/Roll-Off platforms such as LMSR to lower their port ramp to the starboard side of the JHSST topside deck area and have access to three of four SPHB's and the entrance to the cargo deck area ramp.

Ballast System

A vital function of JHSST is to ballast and heel during deploy and recovery of the SPHB's. Additionally, JHSST's semi-submersible capability is a feature required for it to be utilized as a commercial heavy lift ship.

Using accepted standards for the size of the JHSST, it was determined that the JHSST could heel 2 degrees, resulting in the following relationship to the draft of the vessel:



$$x = (\tan 2^\circ) * (53 \text{ m}) = \mathbf{1.85 \text{ meters}}$$

Deployment of the SPHB's required the topside deck area to be submerged. Using the draft increase achieved by heeling, the ballast system would need to support a draft

increase of 7.15 m, as shown in Figure 24, to increase the draft of the JHSST to 15.45 meters.

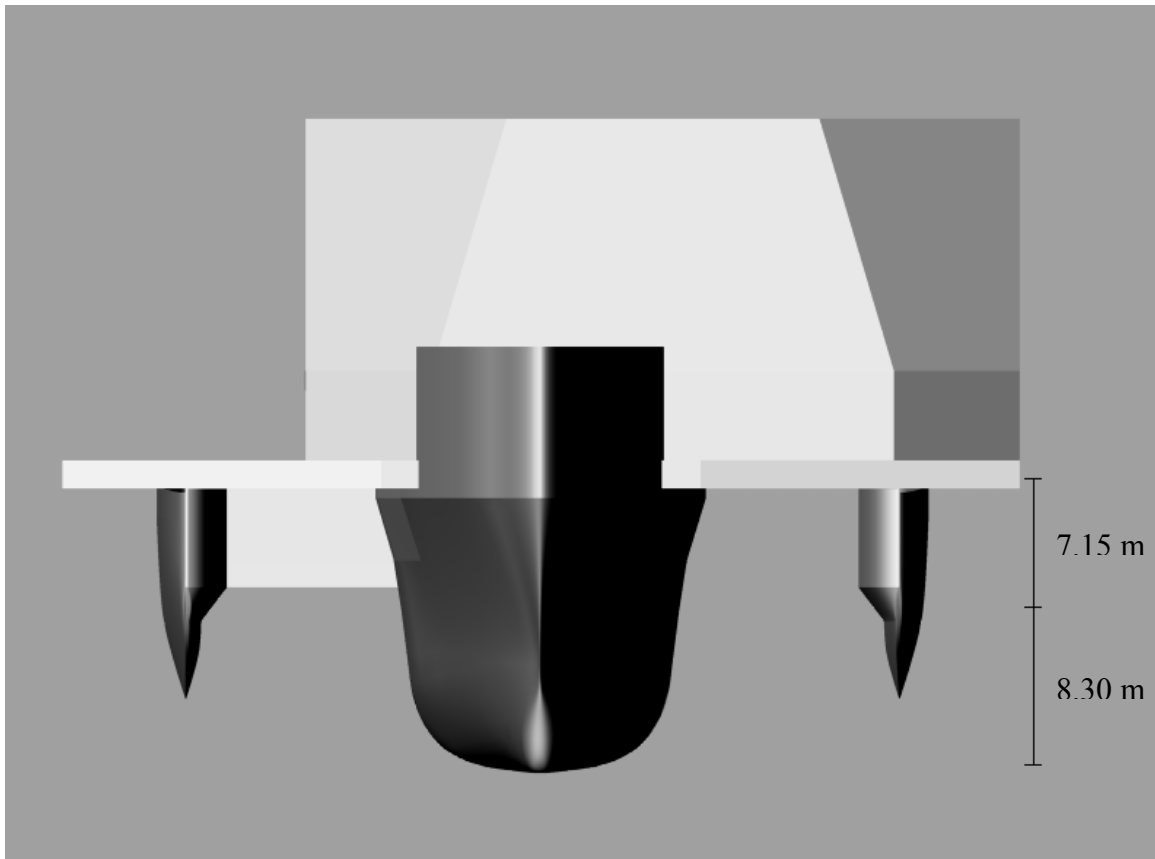


Figure 23 Ballast System Draft Requirements

Using RhinoMarine, a range of water planes were analyzed on the JHSST to determine the volume of the hull underwater at the design draft and at the ballasted draft:

Draft	Volume
8.3 meters	~16,000 m ³
15.45 meters	~57,000 m ³

Table 15 JHSST Draft and Volume Relationship

It was determined that the cargo deck, stern ramp area and machinery spaces occupied a volume of approximately 19,000 m³ inside the hull. It follows that of the 56,000 m³ of volume underwater at the 15.45 meter draft, 37,000 m³ is available for use as ballast:

$$57,000 \text{ m}^3 - 19,000 \text{ m}^3 = \mathbf{38,000 \text{ m}^3}$$

This volume provides us with approximately 38,000 tons of weight:

$$37,000 \text{ m}^3 * 1.025 \text{ tons sea water/m}^3 \approx \mathbf{38,000 \text{ tons}}$$

As seen in table 15, the JHSST provides approximately 56,000 tons of buoyancy at the ballasted draft and approximately 15,000 tons of buoyancy at the normal operating draft. Comparing the difference in buoyancy at these drafts with the amount of weight in the hull that is added through a ballasting system, it was determined that 4,000 tons of weight is required above the water line to achieve the desired draft through ballast:

$$57,000 \text{ tons} - 16,000 \text{ tons} = 41,000 \text{ tons}$$

$$41,000 \text{ tons} - 38,000 \text{ tons} = \mathbf{3,000 \text{ tons}}$$

The JHSST is thus equipped with two ballast tanks of appropriate volumes, forward and aft, to achieve this desired weight.

Weights

The JHSST weight analysis was conducted using a Microsoft Excel spreadsheet originally used for in the Rapid Strategic Lift Ship Hullform Study. The spreadsheet formula constants were scaled from the donor vessel to reflect the characteristics of the JHSST.

SWBS	W _T (MT)	L _{CG} (m)	K _G (m)
W100 – Hull Structure	6109	121	14
W200 – Propulsion Plant	1147	243	13
W300 – Electrical Plant, General	329	158	14
W400 – Command and Surveillance	45	241	34
W500 – Auxiliary Systems, General	745	121	12
W600 – Outfitting + Furnishings, General	493	116	13
W700 – Armament	1.9	234	25
LIGHTSHIP	8870	139	14
D&B Margin (12%, 10%)	1064	139	1.3
LIGHTSHIP W/ MARGIN	9934	139	15
WF	6337	125	11
TOTAL	16271	134	13

Table 16 JHSST Weights

Hydrostatics and Stability

The JHSST hydrostatic and stability analyses were performed using RhinoMarine. Because of time limitations and limited experience levels of the team members, a full hydrostatic analysis was not completed. However, a few general values determined from the weight estimate and RhinoMarine output is listed in Table 17.

Parameter	Value
Vertical Center of Gravity	13 m
Design Draft	8.3 m
Displacement at Design Draft	16,000 tons
Ballast Condition Draft	15.45 m
Displacement at Ballast Condition	57,000 tons

Table 17 JHSST Hydrostatic Characteristics

Power and Propulsion

Hull Resistance

To support the event model developed by the Innovation Cell, the JHSST is required to achieve a transit speed of 24 knots. Additionally, the project team engaged the possibility of achieving a peak speed of 30 knots.

The power required to achieve these speeds was determined using the “Effective Horsepower and Seakeeping Tests on a Trimaran Model².” Comparisons to the location of the side hulls relative to the center hull were made between the iterations of the model test and the JHSST design, and the JHSST design was determined to most closely resembled to “Heavy Displacement Forward Middle” weight and side hull-to-center-hull trimaran arrangement.

The relationship between the shaft horsepower and speed for varying loads, shown in Figure 20, show that 41,970 shaft horsepower is required to achieve 24 knots, while 78,700 shaft horsepower is required to achieve 30 knots.

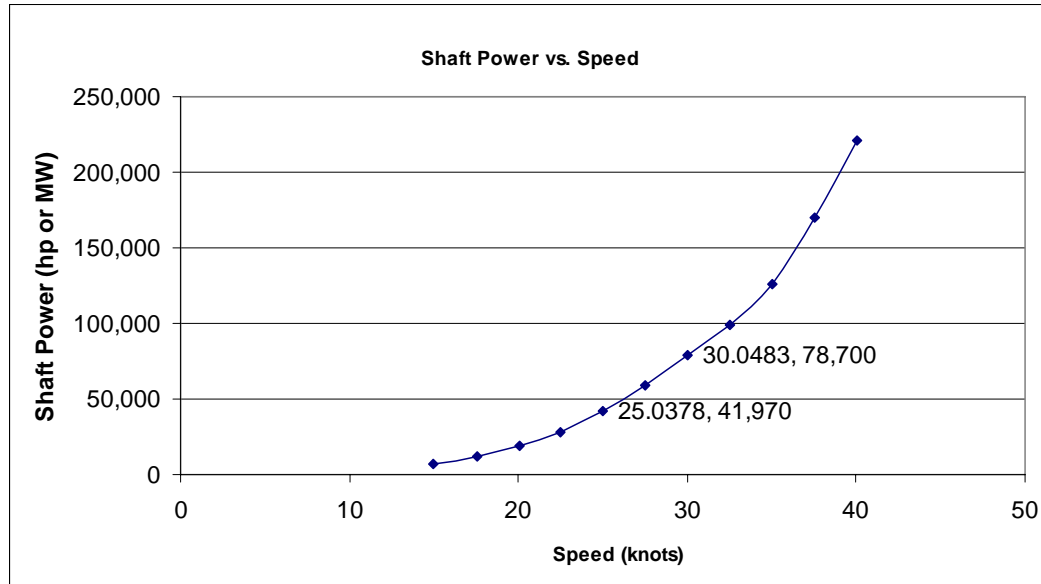


Figure 24 Ship Model Test Results

Power

Using this data, the project team determined that gas turbine engines would be the most desirable method of powering the propulsion system for the JHSST.

Two variants of the General Electric Marine Gas Turbine Engine (GTE), the LM2500 and LM2500+, provide a unique solution to the speed requirements for the JHSST. Summarized in Table 16, the LM2500 GTE provides the requisite shaft horsepower for the JHSST to achieve 24 knots in either loading condition, and the LM2500+ provides the shaft horsepower required for the JHSST to achieve approximately 30 knots in either loading condition.

Parameter	LM2500	LM2500+
Output	33,600 shp	40,500 shp
Fuel Consumption	0.373 lb/shp-hr	0.354 lb/shp-hr
Weight	30,864 lb	33,069 lb
Length	8 m	8.4 m
Width	2.65 m	2.65 m
Height	3 m	3 m

Table 18 LM2500 and LM2500+ Characteristics

From this, the project team concluded that the best option to achieve the requisite speed of 24 knots and desired speed of 30 knots would be to incorporate these two powering configurations as different construction options. Because they share nearly identical dimensions, the LM2500 and LM2500+ could be selectively installed in any JHSST hull constructed dependent on its future missions.

Propulsion

Several options for propulsion were discussed; however, due to strict constraints on the draft and beam of the JHSST, most of these options eliminated early:

- Propellers – The use of propellers require an increase in draft, which is undesirable for this design.
- Azipod propulsion units – Azipod propulsion units of the size requisite for the desired speed of the JHSST are too large to fit in the JHSST's center hull. Since an increase in the beam of the center hull is undesirable, azipod propulsion units were not chosen to be used for propulsion.

It was determined that water jets were the best propulsion option for the JHSST, as they did not require an increase in beam or draft and enabled the JHSST to achieve desired speeds.

The Kamewa Water Jet selected for this vessel has high pump efficiency, and thus is able to provide increased speed and more economical fuel consumption rates.

Additionally, bow thrusters added to the waterjet propulsion system provide the JHSST with a dynamic position capability, as the waterjets are trainable in all directions.

Fuel Capacity

Using fuel consumption rates for GE LM2500 and LM2500+ GTE's, the team determined the following fuel requirements to achieve a range of 6000 nautical miles at 24 knots:

- GE LM2500: 2821.05 MT
- GE LM2500+: 2916.08 MT

The JHSST has space for 3,000 MT of fuel, and thus can meet the range requirements with either propulsion option.

Self Propelled Hover Barge

The Self Propelled Hover Barge is an integral part of the "Seabase to Treeline" Connector system. An extensive description of the SPHB's capabilities and limitations is included in the "Seabase to Treeline" Connector Innovation Cell's report. Since the objective of this project was to detail the design of the Joint High Speed Sea Truck proposed by the Innovation Cell, the conclusions of the analysis of the features and performance of the SPHB were maintained.

In addition to the projected capabilities of the SPHB as described by the Innovation Cell, assumptions were made about the SPHB that affected the design of the JHSST:

- The SPHB is capable of traversing in the ahead and astern direction.

This capability was assumed to support the interface of the SPHB with the JHSST during loading and unloading operations, as shown in Figure 14.

- The SPHB contains a tracked system, which can be used to assist in its recovery and launch from the JHSST.

This capability, discussed in the Innovation Cell's report and shown in Table 15, was included to support the arrangement of the SPHB's on the JHSST. Utilizing the tracked system would allow increased control of the SPHB, useful most specifically during recovery operations to ensure an orderly arrangement of SPHB's.

Parameter	Value
Length	31 m
Beam	23 m
L/B Ratio	1.34
Total Deck Area	737 m²
Cargo Deck Area	553 m
Cargo Area/Deck Area Ratio	75%
All-Up Weight	525 MT
Sustained Speed	8 knots

Table 19 SPHB Characteristics

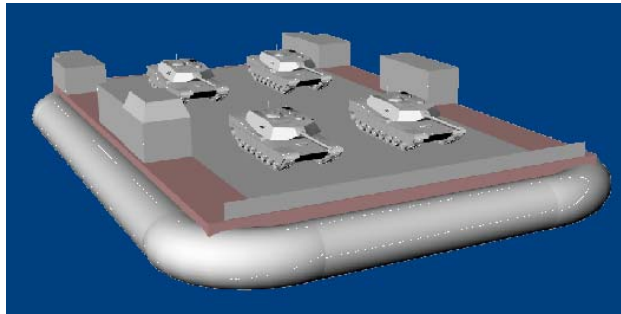


Figure 25 Loaded SPHB

Conclusions and Future Work

It was determined that the High Speed Joint High Speed Sea Truck detailed in this report is the most effective ship design that meets the aforementioned requirements. Its characteristics allow the High Speed Joint High Speed Sea Truck to encompass several significant mission capabilities:

- 24 knots cruising speed / 30 knots maximum speed / Dynamic position capable
- 6000 nautical mile range (at 24 knots)
- Semi-submersible
- Capable of sustained operations in sea state 5
- Capable of supporting aviation operations
- Easily interface with existing platforms such as MLP and LMSR

The High Speed Joint High Speed Sea Truck ensures the delivery of the 2015 MEB in less than 8 hours, fully encompasses Homeland Security logistics support, short sea

shipping, commercial heavy lift missions, and is capable of transporting large military cargo and smaller damaged ships.

Future Work

Future work in the design of the High Speed Joint High Speed Sea Truck was identified as a necessary continuation of this project:

- The center and side hull forms were created using existing hull form shapes. Further work should be conducted to create a hull form that is best suited for this ship.
- The hull resistance of the High Speed Joint High Speed Sea Truck was estimated using results from “Effective Horsepower and Seakeeping Tests on a Trimaran Model².” A model test of the hull form should be conducted in the future to confirm the assumptions made using the referenced model test.
- Operations that the High Speed Joint High Speed Sea Truck will conduct will require the use of a crane. Because of its minimal impact to the design, an analysis of the requirements for a crane was not conducted, but should be in the future.
- The High Speed Joint High Speed Sea Truck will utilize a stern ramp on the cargo deck (first level) to access the cargo area from a med-moor position. Due to time constraints and the foreseen simplicity of the stern ramp, a design of the stern ramp was not conducted, but should be in the future.
- The Self Propelled Hover Barge is a critical element in the delivery of the primary mission payload in the time requirement of eight hours. Because of this, future work to ensure their capabilities are consistent with the assumptions made, as well as work to ensure their maximum operability should be conducted.
- Due to time constraints, the specifications of the ballasting systems were not determined. Because of its necessity to the ship’s missions, the ballasting system should be described in detail in future work.
- The specific hydrostatic properties, including roll period, of the JHSST were not determined due to time constraints and should be explored in future work.

Science and Technology Issues

All of the capabilities and features of the High Speed Joint High Speed Sea Truck are feasible with today’s technology. However, “Seabase to Treeline” Connector System Innovation Cell identified several issues with assumptions regarding the Self Propelled Hover Barges. Since this project did not detail any design for the SPHB’s, those issues still exist:

- Variable Lift Capability
- Retractable or Rotating Outdrives/Tracks
- IPS Propulsion

References

1. Chafin, Good, and Milbert. "Seabase to Treeline" Connector Innovation Cell. August 2005.
2. Harris. "Effective Horsepower and Seakeeping Tests on a Trimaran Model," March, 1999.
3. *Federation of American Scientists*. 2005. <http://www.fas.org/man/dod-101/sys/land/index.html> August 2005.
4. *Rolls Royce Kamena Waterjets, S-Series Fact Sheet*." <http://www.rolls-royce.com>. May 2004.
5. Dokkun. "Ship Knowledge: A Modern Encyclopedia," 2003.

Appendix A – Assumed Payload, 2015 Marine Expeditionary Brigade Surface Element

<u>Item</u>	<u>#</u>	<u>Length (m)</u>	<u>Width (m)</u>	<u>Height (m)</u>	<u>Weight (MT)</u>	<u>Total Payload (MT)</u>
M1A1	14	7.93 m	3.66 m	2.63 m	57.22	801.07
AAAV	48	9.10 m	3.66 m	3.18 m	28.53	1369.44
M88A1	1	8.21 m	3.38 m	3.40 m	48.93	48.93
M1097	99	5.01 m	2.18 m	2.59 m	3.86	382.34
M198	18	7.52 m	2.82 m	2.18 m	8.00	144.02
LVS Mk48	2	11.58 m	2.44 m	2.59 m	25.40	50.80
M101A2	20	3.73 m	1.91 m	2.13 m	0.63	12.64
M390	21	4.72 m	2.44 m	2.24 m	2.32	48.69
LAV	25	6.99 m	2.67 m	2.67 m	15.73	393.19
Mk1 GI Joe	2226	1.50 m	1.20 m	2.00 m	0.20	445.20
FRKLFT	7	8.86 m	2.57 m	2.72 m	15.02	105.16
AVLB	1	9.67 m	3.60 m	2.25 m	54.70	54.70
MEWSS	3	6.99 m	2.67 m	2.67 m	15.73	47.18
MTVR	133	8.70 m	2.46 m	3.53 m	11.79	1568.52
MRC	33	4.85 m	2.31 m	1.83 m	4.67	154.18
M9293/Q46	4	7.98 m	2.46 m	3.53 m	10.87	43.50
ABV	2	12.04 m	3.66 m	2.90 m	49.90	99.79
					TOTAL:	5769 MT